National Aeronautics and Space Administration

NASA Conjunction Assessment Risk Analysis Approach

Lauri K. Newman
NASA Robotic Conjunction Assessment Manager

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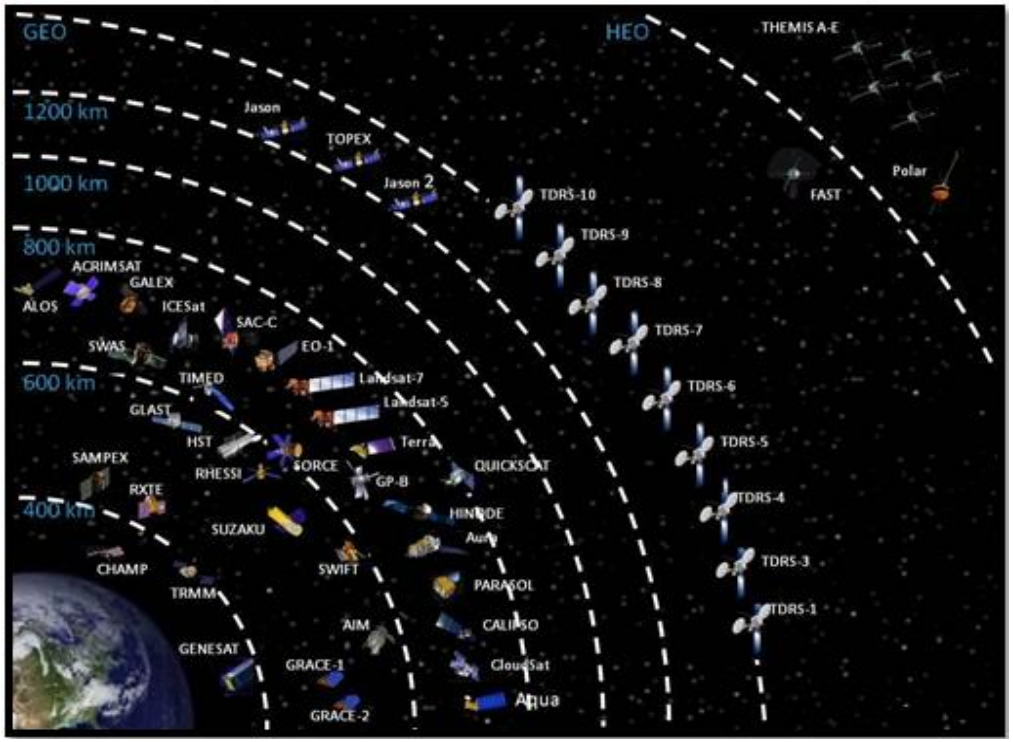
NASA ROBOTIC CARA

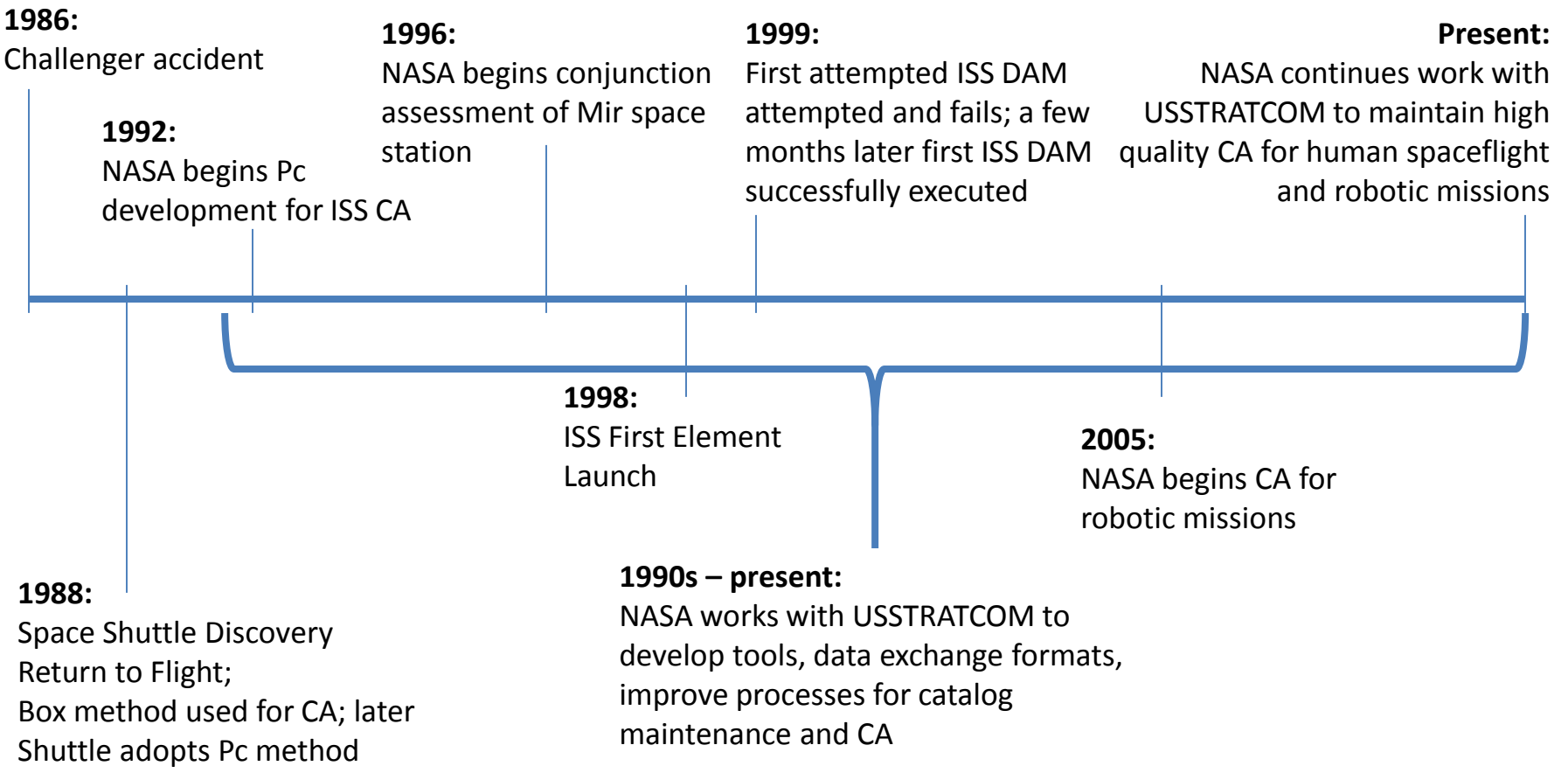
www.nasa.gov

NASA's Process: CARA

- NASA is committed to safety of flight for all of its operational assets
  - Performed by CARA at NASA GSFC for robotic satellites
    - Focus of this briefing
  - Performed by TOPO at NASA JSC for human spaceflight
- The Conjunction Assessment Risk Analysis (CARA) was created to offer this service to all NASA robotic satellites
  - Currently provides service to ~65 operational satellites
    - NASA unmanned operational assets
    - Other USG assets (USGS, NOAA)
    - International partner assets

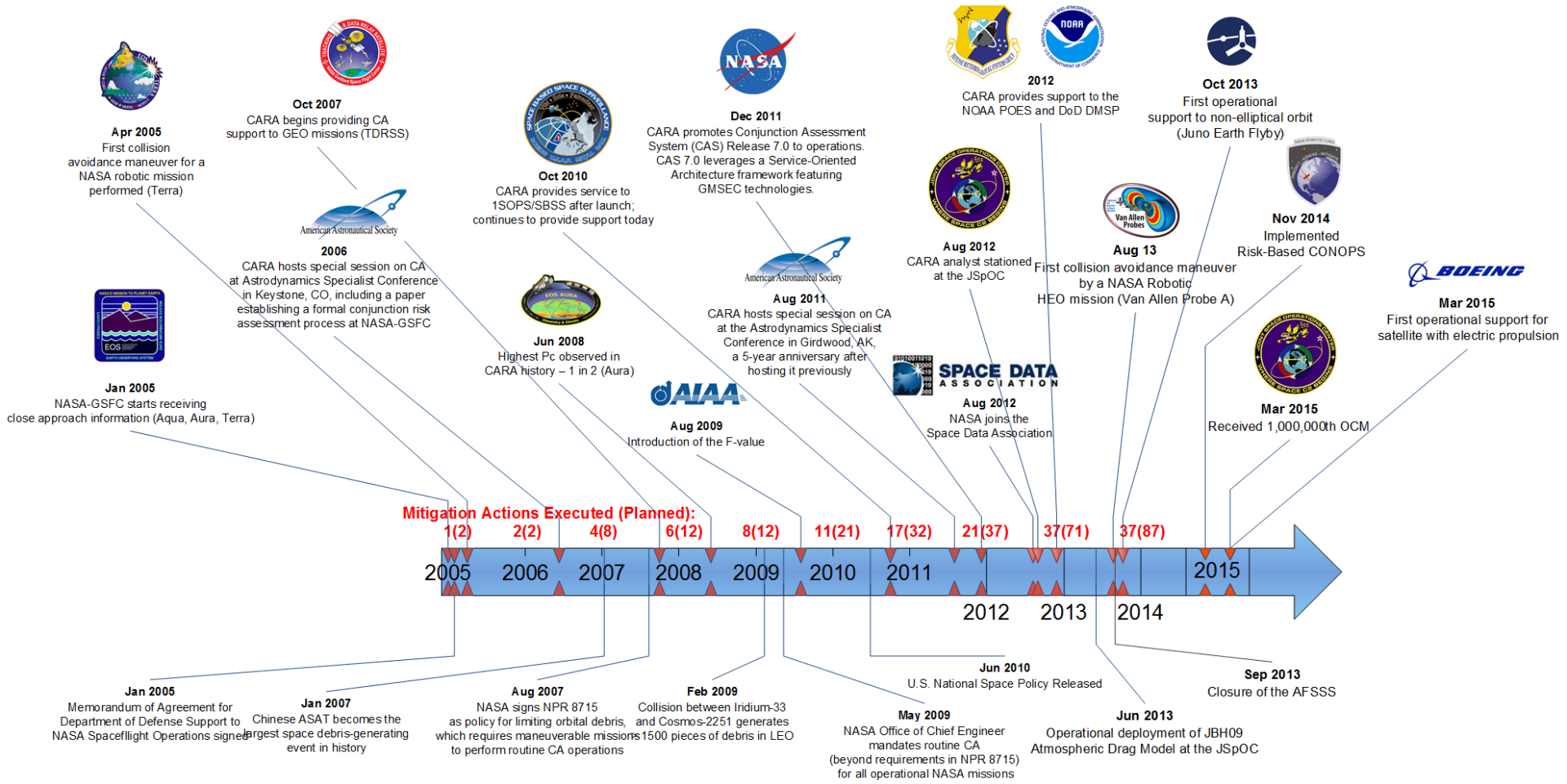


NASA Human Spaceflight Conjunction Assessment (CA) History

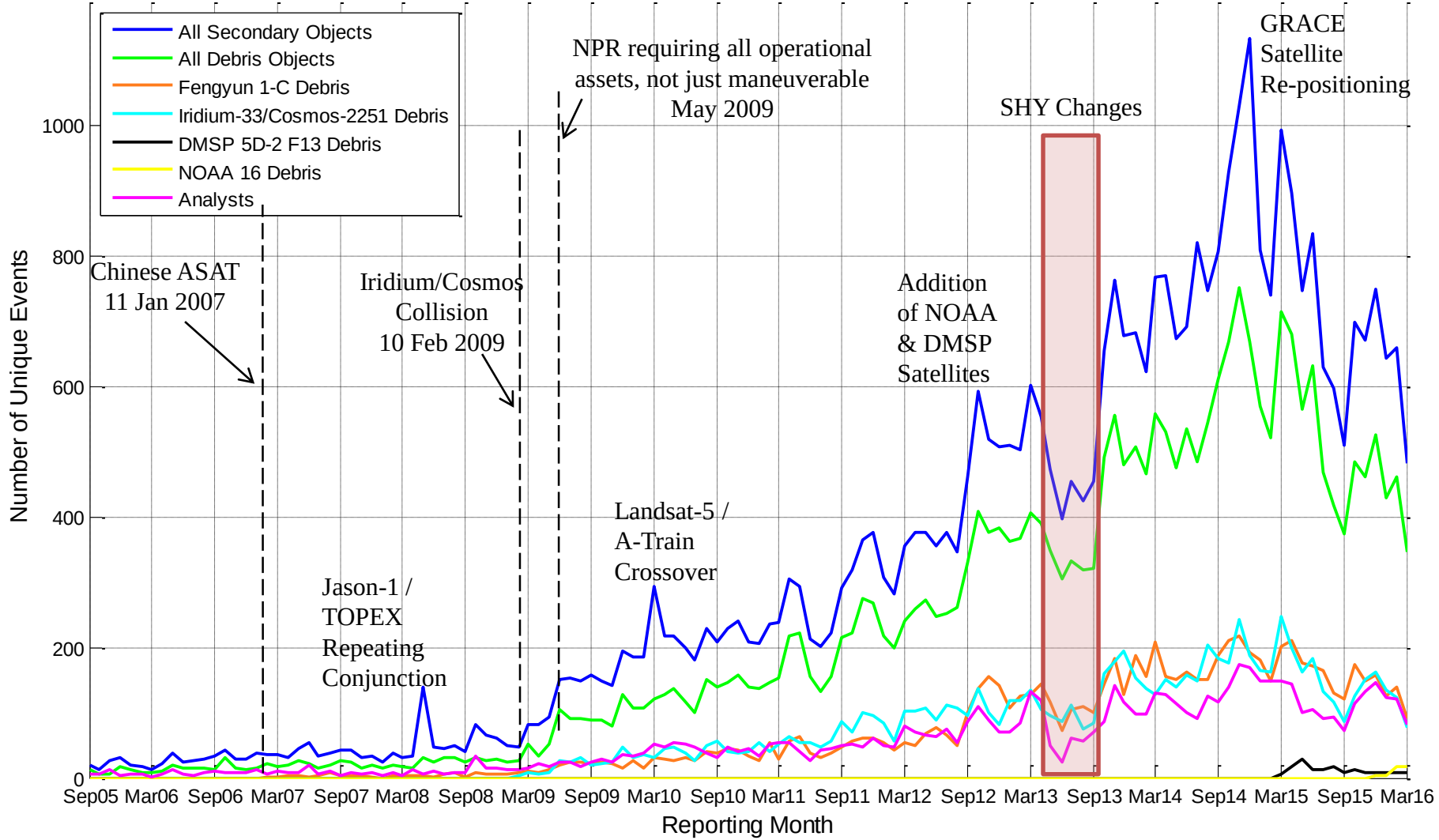


NASA has performed CA for 25 years. Initial USSTRATCOM capability developed with NASA.

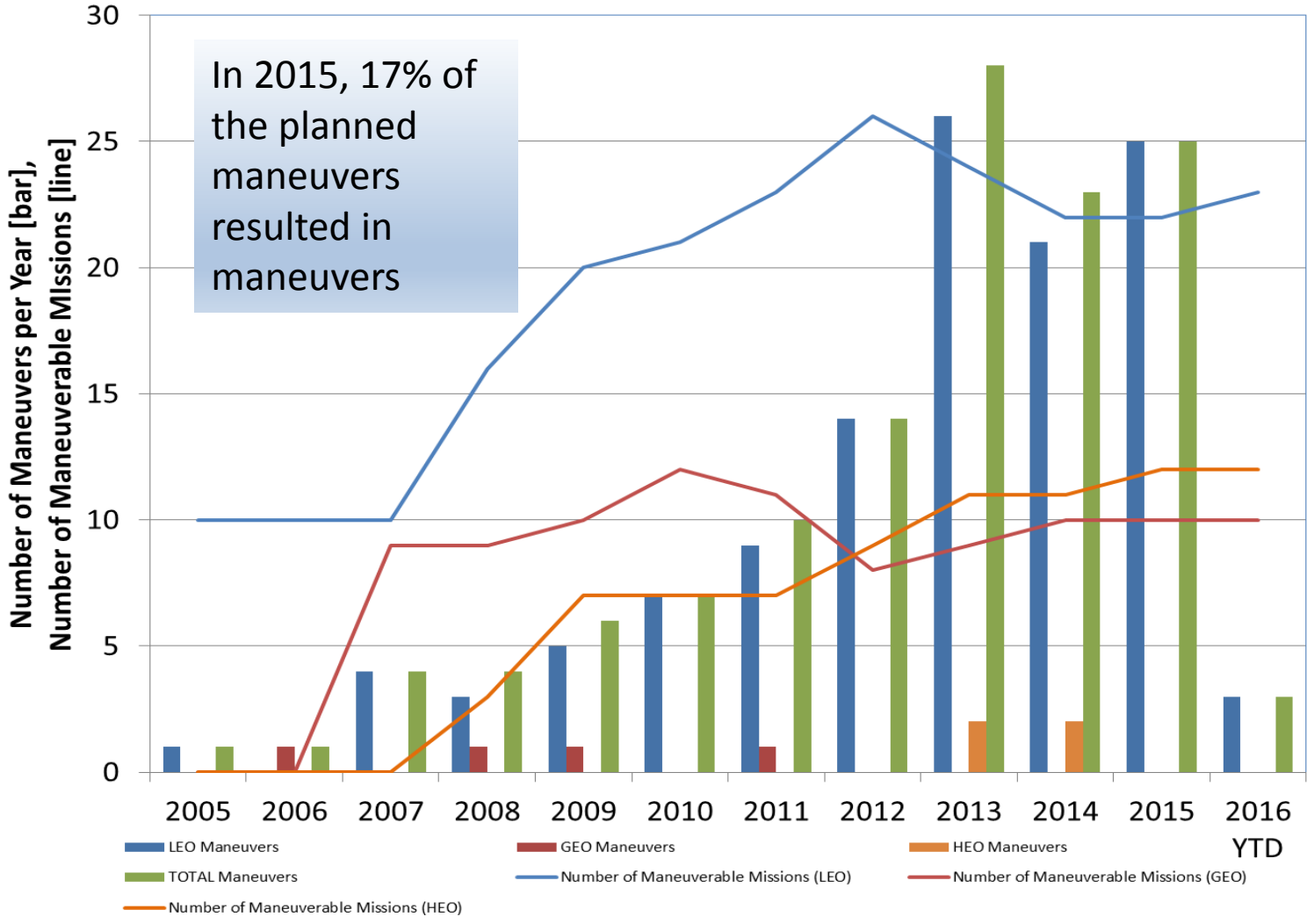
NASA Robotic CARA History



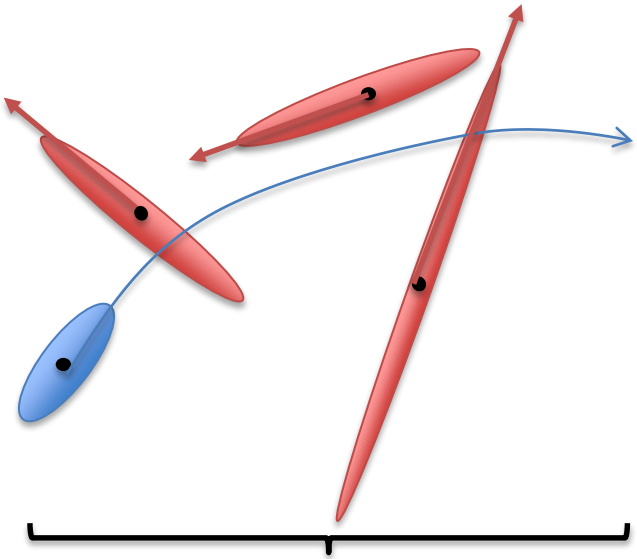
Mission Context: Number of Conjunctions in LEO



Collision Avoidance Maneuver History

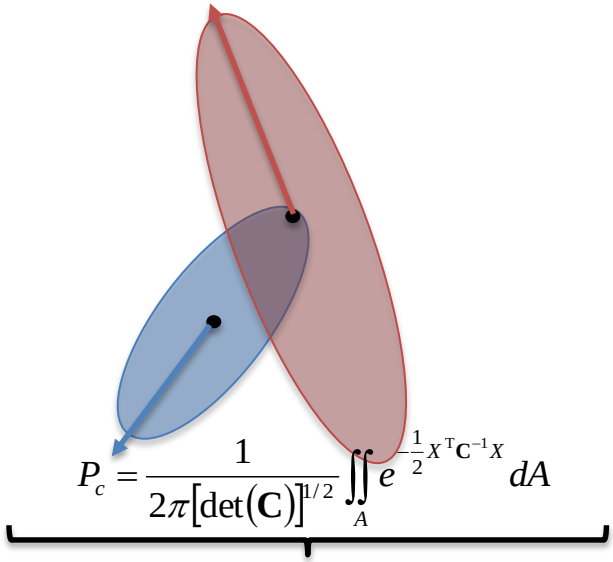


The CARA Process Helps Manage On-Orbit Collision Risk



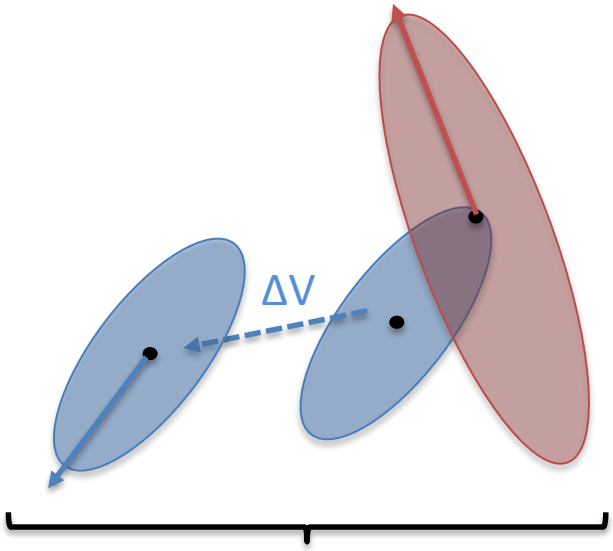
Conjunction Assessment (CA) is the process of identifying close approaches between two orbiting objects; sometimes called conjunction "screening"

The **Joint Space Operations Center (JSpOC)** – a USAF unit at Vandenberg AFB, maintains the high accuracy catalog of space objects, screens CARA-supported assets against the catalog, performs OD/tasking, and generates close approach data



CA Risk Analysis (CARA) is the process of assessing collision risk and assisting satellites plan maneuvers to mitigate that risk, if warranted

The **CARA** Team at NASA-GSFC provides CARA for all NASA operational robotic satellites, as well as a service provider for some other external agency/organizations

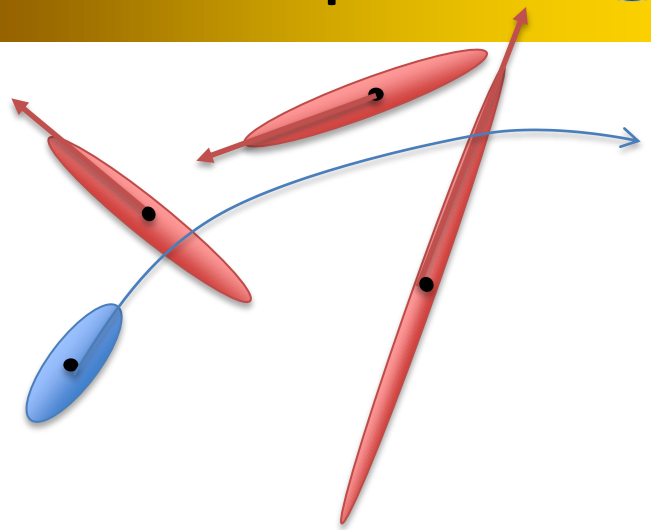


Collision Avoidance (COLA) is the process of executing mitigative action, typically in the form of an orbital maneuver, to reduce collision risk due to a conjunction

Each satellite **Owner/Operator (O/O)** – mission management, flight dynamics, and flight operations – are responsible for making maneuver decisions and executing the maneuvers

CARA Operational Process: Close Approach Predictions at the JSpOC

- The JSpOC maintains an accurate state for all trackable objects
- In support of CARA, the dedicated Orbital Safety Analysts (OSA)
  - Perform routine screenings – 3x day for LEO, 1x for GEO/HEO
    - Against JSpOC's Astrodynamics Support Workstation (ASW) solution and the O/O solution if available
  - Inspect orbit determination; perform manual orbit determination, if warranted
  - Adjudicate tasking level of secondary objects; request increased tasking, if warranted
  - Generate and deliver necessary data products
- JSpOC is staffed by Goddard-dedicated OSA 20 hours/ day

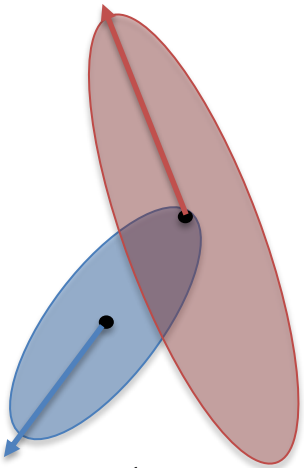


The **Screening Duration** is the "lookout" period of time for which conjunctions are identified. This is 7 days for LEO assets and 10 days for GEO/HEO assets

The **Screening Volume** is the geometric volume placed around the asset during the conjunction screening process; any objects that violate this volume trigger data products to be generated and delivered. The screening volumes are re-sized annually by CARA using a 95% capture of the relative uncertainties in each orbital regime based two-year moving window historical conjunction data

CARA Operational Process: NASA Robotic Collision Risk Analysis

- CARA is responsible for assessing, communicating, and assisting with mitigation of on-orbit collision risk
- As data is received, the CARA system automatically processes that data, and generates & delivers
  - **CARA Summary Reports** to O/O
  - **Work List** to JSpOC OSAs
- CARA team performs routine risk analysis
  - Pc; Pc sensitivity
  - Conjunction Geometry
  - OD Evaluation / Solution Consistency
  - Space Weather Sensitivity
  - Maneuver planning & evaluation
- For high-risk conjunctions, CARA builds and delivers a **High Interest Event (HIE) briefing** with detailed analyses, and planning & decision information



$$P_c = \frac{1}{2\pi\left[\det(\mathbf{C})\right]^{1/2}} \iint_A e^{-\frac{1}{2}X^{\mathrm{T}}\mathbf{C}^{-1}X}\, dA$$

The **Collision Probability (Pc)** is the probability that, given the uncertainty in the two objects' positions as described by their covariance matrix, that the actual miss distance is less than the hard-body region

Maneuver Planning

- A trade-space contour plot shows the effect that a range of phase times and delta-v magnitudes have on miss distance
  - Single conjunction event (top)
  - Multiple events (bottom)
- Assists with initial maneuver planning
  - Save time-expensive iteration cycles for high fidelity maneuver planning
  - Does not presume any constraints about satellite maneuver capability or conjunction mitigation strategies—allows flight support teams to decide on course of action